

5 What is claimed is:

1. A method for adjusting keystone in a projector, comprising:
 - (a) sensing using an imaging device at least two boundaries defining a projection screen;
 - 10 (b) determining a transformation to adjust the keystone of an image projected from said projector;
 - (c) modifying said image projected from said projector in accordance with said transformation;
 - 15 (d) projecting said modified image from said projector, wherein said imaging device and said projector are maintained in a fixed relationship with respect to each other.
2. The method of claim 1 wherein said at least two boundaries include a pair of corners of said projection screen.
- 20 3. The method of claim 1 wherein said at least two boundaries include a pair of edges of said projection screen.
- 25 4. The method of claim 1 wherein said at least two boundaries includes four corners of said projection screen.
5. The method of claim 1 wherein said at least two boundaries includes four edges of said projection screen.
- 30 6. The method of claim 1 wherein said keystone includes horizontal adjustment.

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7. The method of claim 1 wherein said keystoneing includes vertical adjustment.

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8. The method of claim 1 wherein said keystoneing includes adjustment in two different directions.

9. The method of claim 1 wherein said imaging device is integral with said projector.

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10. A method for adjusting keystoneing in a projector, comprising:

- (a) initiating a keystoneing adjustment process;
- (b) sensing using an imaging device an image projected by said projector;
- (c) adjusting the focus of said projector;
- (d) determining a transformation to adjust the keystoneing of an image projected from said projector;
- (e) modifying said image projected from said projector in accordance with said transformation;
- (f) projecting said modified image from said projector; and
- (g) wherein steps (b) through (e) are free from user input.

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11. The method of claim 10 wherein step (b) is performed after step (a).

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12. The method of claim 10 wherein said initiating is by pressing a button of said projector.

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13. The method of claim 10 wherein said imaging device is a camera maintained in a fixed relationship with respect to said projector.

14. The method of claim 13 wherein said camera is offset with respect to a projection lens of said projector.

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15. The method of claim 14 further comprising another imaging device sensing said image.

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16. The method of claim 10 further comprising another imaging device sensing said image.

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17. The method of claim 10 wherein said adjusting is based upon said sensing, said determining is based upon said adjusting, said modifying is based upon said determining, and said projecting is based upon said modifying.

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18. A method for adjusting keystone in a projector, comprising:

(a) initiating a keystone adjustment process;

(b) sensing using an imaging device an image projected by said projector;

(c) adjusting the focus of said projector in response to initiating said keystone adjustment process;

(d) determining a transformation to adjust the keystone of an image projected from said projector;

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(e) modifying said image projected from said projector in accordance with said transformation;

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- (f) projecting said modified image from said projector; and
- (g) wherein step (c) is free from user input.

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19. The method of claim 18 wherein a user initiates said keystoneing adjustment process.

20. The method of claim 18 wherein a user initiates said keystoneing process using a remote control of said projector.

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21. The method of claim 18 wherein said determining is free from user input.

22. The method of claim 18 wherein said modifying is free from user input.

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23. The method of claim 18 wherein said determining is based upon user input.

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24. A method for adjusting keystoneing in a projector, comprising:

- (a) sensing using an imaging device a desired keystone adjustment directed by a user;
- (b) determining a transformation to adjust the keystoneing of an image projected from said projector in accordance with said desired keystone adjustment;
- (c) modifying said image projected from said projector in accordance with said transformation;
- (d) projecting said modified image from said projector; and

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- (e) repeating steps (b) through (d) while said user maintains said desired keystone adjustment.

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- 25. The method of claim 24 wherein a pattern is projected by said projector that is sensed by an imaging device.

- 26. The method of claim 25 wherein said pattern has different frequencies.

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- 27. The method of claim 25 wherein said user maintains is based upon said user pointing with a pointer.

- 28. The method of claim 27 wherein said pointer is an optical pointer.

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- 29. The method of claim 28 wherein said optical pointer is sensed by said imaging device.

- 30. The method of claim 24 wherein said user indicated a direction of adjustment of said keystone adjustment.

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- 31. The method of claim 30 wherein said direction may be one of a plurality of directions.

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- 32. The method of claim 24 wherein said user observes a dynamically changing said image in response to said keystone adjustment.

- 33. The method of claim 31 wherein said directions are indicated on a remote control for said projector.

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34. A method for adjusting the ratio of width to length of an image projected from a projector, comprising:
- (a) said projector receiving user input indicating a desired modification of the ratio of said width to length of said image projected from said projector;
 - (b) determining a transformation to adjust said image projected from said projector in accordance with said desired ratio modification;
 - (c) modifying said image projected from said projector in accordance with said transformation;
 - (d) projecting said modified image from said projector; and
 - (e) repeating steps (b) through (d) while said user maintains said desired ratio modification.
35. The method of claim 34 wherein a pattern is projected by said projector that is sensed by an imaging device.
36. The method of claim 35 wherein said pattern has different frequencies.
37. The method of claim 35 wherein said user maintains is based upon said user pointing with a pointer.
38. The method of claim 37 wherein said pointer is an optical pointer.
39. The method of claim 38 wherein said optical pointer is sensed by said imaging device.

- 5 40. The method of claim 34 wherein said user indicated a direction of adjustment of said ratio modification.
41. The method of claim 40 wherein said direction may be one of a plurality of directions.
- 10 42. The method of claim 44 wherein said user observes a dynamically changing said image in response to said ratio modification.
43. The method of claim 41 wherein said directions are indicated on a remote control for said projector.
- 15 44. A method for determining the location of a screen by a projector, comprising:
- (a) said projector receiving an image of a potential said screen;
- 20 (b) said projector performing a median filter operation on said image;
- (c) said projector performing a gradient operation on said image;
- (d) said projector performing a zero-crossing operation on said image to determine edge screen candidates;
- (e) said projector matching pairs of said edge screen candidates;
- 25 (f) said projector using statistical inference to select said matching pairs for said location of said screen.
45. The method of claim 44 wherein steps (a), (b), (c), (d), (e), and (f) are performed in the order of steps (a), (b), (c), (d), (e), and (f).
- 30 46. The method of claim 44 wherein said location is relative to said projector.

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47. The method of claim 44 wherein said image is received by an imaging device.

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48. The method of claim 47 wherein said imaging device includes a one-dimensional sensor.

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49. A method for adjusting keystone in a projector, comprising:

- (a) sensing using a plurality of imaging devices an image projected from said projector;
- (b) determining a transformation to adjust the keystone of said image projected from said projector;
- (c) modifying said image projected from said projector in accordance with said transformation;
- (d) projecting said modified image from said projector, wherein said plurality of imaging devices is free from including the projector optics from which said image is projected of said projector.

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50. The method of claim 49 wherein at least one of said imaging devices and said projector are maintained in a fixed relationship with respect to each other.

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51. The method of claim 49 further comprising sensing a projection screen by said imaging devices.

52. The method of claim 49 wherein said modifying includes digital image processing.

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53. The method of claim 49 wherein said modifying includes optical image processing.

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54. The method of claim 49 wherein said modifying includes mechanical image processing.

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55. A method for adjusting keystoneing in a projector, comprising:

(a) sensing using an imaging device an image projected from said projector;

(b) determining a transformation to adjust the keystoneing of said image projected from said projector;

(c) modifying said image projected from said projector in accordance with said transformation;

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(d) projecting said modified image from said projector, wherein said projector includes calibration parameters characterizing different optical settings of the projector optics from which said image is projected of said projector.

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56. The method of claim 55 wherein said imaging devices is free from including the projector optics from which said image is projected of said projector.

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57. The method of claim 55 wherein said imaging device includes the projector optics from which said image is projected of said projector.

58. The method of claim 55 wherein only a single non-projector optics imaging device is included with said projector.

- 5 59. The method of claim 55 wherein said calibration parameters include a lens control parameter.
60. The method of claim 55 wherein said calibration parameters includes zooming of the lens.
- 10 61. The method of claim 55 wherein said calibration parameters include focusing of the lens.
62. The method of claim 55 wherein said calibration parameters includes shifting of the lens.
- 15 63. The method of claim 55 wherein said calibration parameters are stored in memory.
- 20 64. The method of claim 63 wherein said memory is in the form of a look up table.
65. A method for adjusting a projector, comprising:
- 25 (a) sensing using an imaging device a projection screen;
- (b) performing auto-focus of said projector;
- (c) performing auto-positioning of an image with respect to said projection screen;
- (d) performing auto-zooming of said image with respect to said projection ;
- 30 (e) determining a transformation to adjust the keystone of an image projected from said projector;
- (f) modifying said image projected from said projector in accordance with said transformation;

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(g) projecting said modified image from said projector, wherein steps (b), (c), (d), (e), and (f), are performed free from user interaction with said projector.

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66. The method of claim 65 wherein said step (b) through step (f) are performed by the user depressing a single button.

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67. The method of claim 65 wherein said auto-focus focuses said image on said projection screen.

68. The method of claim 65 wherein said auto-positioning centers said image on said projection screen.

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69. The method of claim 65 wherein said auto-positioning is in response to determining the location of said projection screen.

70. The method of claim 65 wherein said auto-zooming is in response to determining the location of said projection screen.

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71. The method of claim 65 wherein said transforming is in response to determining the location of said projection screen.

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72. The method of claim 65 wherein said imaging device and said projector are maintained in a fixed relationship with respect to each other.

73. A method for estimating the depth of a projected image from a projector, comprising:

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- (a) sensing using an imaging device at least two boundaries defining a projection screen; and
- (b) estimating said depth based upon defining said projection screen with a constraint that said projection screen is planar.

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74. The method of claim 73 further comprising the step of projecting said image from said projector.

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75. The method of claim 73 wherein said estimating is based upon determining at least two corners of said projection screen.

76. The method of claim 73 wherein said estimating is based upon determining at least four corners of said projection screen.

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77. The method of claim 73 wherein said imaging device is a 1-dimensional sensor.

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78. A method for rotating an image projected from a projector, comprising:

- (a) sensing using an imaging device a projection screen;
- (b) determining a transformation to adjust said image projected from said projector in accordance with the alignment of said projection screen;
- (c) modifying said image projected from said projector in accordance with said transformation;
- (d) projecting said modified image from said projector.

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- 5 79. The method of claim 78 wherein said projection screen is rectangular.
80. The method of claim 79 wherein said image is rectangular.
- 10 81. The method of claim 80 wherein the lower edge of said projection screen
 is horizontally aligned with respect to a user.
82. The method of claim 81 wherein the lower edge of said image is
 horizontally aligned with respect to a user.
- 15 83. The method of claim 78 wherein said modifying is performed after
 adjusting said image for a keystone effect.
84. A method for adjusting keystone in a projector, comprising:
 (a) sensing using an imaging device at least two boundaries and less
20 than four boundaries defining a projection screen;
 (b) determining a transformation to adjust the keystone of an image
 projected from said projector;
 (c) modifying said image projected from said projector in accordance
 with said transformation;
25 (d) projecting said modified image from said projector.
85. The method of claim 84 wherein said imaging device and said projector
 are maintained in a fixed relationship with respect to each other.
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